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Jose, who took charge of all questions relating to health; and Messrs. G. F. MARSH and W. L. SKINNER, of Lone Pine, California.

W. W. CAMPBELL.

NOTE ON THE MAGNETIC FIELD IN SUN-SPOTS.

In a preliminary note printed in *Publications of the Astronomical Society of the Pacific,* **20,** 220, 1908, it was shown that the evidence then available indicated the existence of a strong magnetic field in sun-spots. A summary of the results hitherto obtained in this investigation is given below:—

(1) In the spectra of sun-spots most of the Fraunhofer lines are widened, some are changed to doublets (incompletely resolved quadruplets), and some to triplets. Others probably have a still more complex structure.

(2) The component lines of spot doublets are circularly polarized in opposite directions (longitudinal effect in a magnetic field).

(3) Many lines not resolved in the spot spectrum are displaced when the Nicol (used with a Fresnel rhomb before the spectrograph slit) is rotated.

(4) When the Nicol, used with rhomb, is set at a certain angle, it transmits the red components of doublets in the spectrum of a right-handed vortex, and the violet components in a left-handed vortex.

(5) Although the larger spots in the northern and southern hemispheres of the Sun are usually found to be of opposite polarity, it frequently happens that spots of opposite polarity occur in the same hemisphere, sometimes in the same spot group.

(6) Triplets have been found in all our best photographs of spot spectra, including those taken when the spot was near the center of the Sun.

(7) The central component of such triplets is plane polarized, while the outer components are elliptically polarized.

(8) Many lines which are widened but not resolved in spot spectra can be shown to be triplets by cutting out the central component with a Nicol placed at a suitable angle.

(9) Under certain conditions, when a Nicol is used, the central line of a spot triplet is present on one side of the spot

and absent on the other. Rotation of the Nicol through 90° reverses the appearance, causing the line to appear on the side where it was previously absent and to disappear on the opposite side. This effect is provisionally attributed to the rotation of the plane of polarization of the plane polarized light emitted by the central line, when passing outward through the spot vapors.

(10) The width of the components of a spot triplet sometimes varies with the position of the Nicol. This may be the result of the combined effect of the rotation of the plane of polarization and the rapid decrease upward in the strength of the field above the spot.

(11) The intensity of the central line of spot triplets varies with the position of the spot on the Sun's surface, and is greatest near the limb.

(12) The intensity of the central line in a spot near the center of the Sun is such as to indicate that the lines of force of the magnetic field usually make a considerable angle with the solar radius passing through the spot.

(13) Lines which appear as doublets in the spot spectrum are found in the laboratory to be doublets when observed along the lines of force, and quadruplets when observed across the lines of force. With the dispersion available, such lines cannot be resolved into quadruplets in the spot spectrum.

(14) Spot triplets are found in the laboratory to be triplets when observed across the lines of force.

(15) Certain triplets and quadruplets of iron show nearly the same relative separation of their components in spot and laboratory.

(16) From the measurement of such lines, the maximum strength of the field is found to range from 2900 to 4500 C. G. S. units in different spots.

(17) The strength of the field is generally greatest near the center of the umbra and decreases gradually in intensity across the penumbra.

(18) An appreciable field is shown by certain lines to extend beyond the boundaries of the penumbra.

(19) Magnetic fields have also been found on the solar disk entirely outside of sun-spots.

(20) The doublets and triplets of iron give the strongest fields hitherto measured in sun-spots. The *D* lines of sodium and the *b* lines of magnesium, which are produced at a higher level in the solar atmosphere, indicate a much weaker field. The hydrogen lines over sun-spots, representing a still higher level, give no indication of a magnetic field. It therefore follows that the strength of the field in sun-spots rapidly decreases in passing upward from the surface of the photosphere.

(21) Preston's law, $\frac{\Delta\lambda}{\lambda^2} =$ const., is closely followed by iron doublets observed in the laboratory (using mean values of $\Delta\lambda$) and approximately so by spot doublets.

(22) The degree of widening of unresolved lines in the spot spectrum decreases rapidly from the red to the violet, and is roughly proportional to the separation of their components in the laboratory.

(23) A direct relationship appears to exist between the strengthening and the widening of lines in spot spectra.

(24) As the strength of the field is greatest at low levels, it appears probable that the electric vortex which produces the field lies within the photosphere.

(25) The strength of the field in sun-spots is not sufficient to account for magnetic storms on the earth.

Charts of the magnetic fields in sun-spots, showing their strength and polarity in all parts of a spot group and the surrounding regions, are made photographically as follows:—

Above the spectrograph slit a Fresnel rhomb (or a quarter-wave plate) and a Nicol prism are mounted, the position of the Nicol being such as to cut off one of the side components of a triplet. A series of exposures is then made, with the slit set across different parts of a spot group. The spot lines thus photographed are distorted, the red components appearing in spots of one polarity, the violet components in those of the opposite polarity. The displacement of the components from the normal position of the line is proportional to the strength of the field. It frequently happens that closely adjoining spots in the same group are of opposite polarity. In a recent case (September 25, 1909) a large spot was accompanied by four small spots, all lying within the same penumbra. The polarity of the magnetic field in the penumbra (on the side away from the small spots) was the same as that of the large spot. All of the small spots, however, were of opposite polarity. Between the large and small spots the magnetic fields of opposite polarity counteracted one another, reducing the strength of the resultant field to zero. This is shown on the photographs by the form of the lines: the red components bend sharply back from the position of maximum displacement over the large spot to the normal position of the line, where they cross to the violet side, returning again to normal in the region beyond the small spots.

By means of a series of parallel slits, the spectra of from six to ten sections of a spot group can be photographed simultaneously, in parallel strips on a single negative. A simple apparatus then permits images of any desired line in this negative to be photographed side by side, in the same relative positions as the parallel slits of the spectrograph. A photograph of the hydrogen flocculi, made with the $H\alpha$ line, is then copied on the same plate.[1] The composite image shows the strength and polarity[2] of the magnetic fields along the lines occupied by the slits, and permits the relationship between the magnetic fields and the curvature of the streamers in the $H\alpha$ vortices to be investigated. Results already obtained with provisional apparatus show this relationship to be an intimate one.

George E. Hale.

Spectrographic and Photographic Observations of Comet *c* 1908 (Morehouse).[3]

So exceedingly faint was the nucleus of this comet that great difficulty was experienced in securing a slit spectrogram. An exposure was finally made with the one-prism spectrograph of the D. O. Mills Expedition extending over seven hours and twenty-nine minutes on the nights of February 24, 25, and 26, 1909. The width of the slit was 0.5^{mm} and precautions were taken to keep the temperature of the

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[1] Perfect registration is readily secured by the aid of a photograph of the spot group, reflected from the polished slit jaws into a camera, showing the exact positions of the slits with reference to the spots.

[2] With high dispersion the direction of the field can also be determined by the intensity of the central line of a triplet.

[3] Abstract of *Lick Observatory Bulletin*, No. 163.